

EFFECTS OF FLUX APPLICATION AND MELTING PARAMETERS IN  
INVESTMENT CASTING OF PURE ALUMINIUM BY IN-SITU MELTING  
TECHNIQUE

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I dedicate this thesis to my lovely, husband, children and family.



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## ABSTRACT

Investment cast aluminium suffers porosity defect attributed to the complex combination of various factors including melt quality, casting process parameter and pouring technique. Even though, melt treatment and controlled of the process parameter have promising result, however turbulence developed during pouring of molten aluminium increasing the formation of porosity as a result of the entrainment of the surface oxide ( $\text{Al}_2\text{O}_3$ ) film known as bifilm. Currently, turbulence free filling system was applied in casting process using tilt casting, bottom filling integrated with low pressure and also in-situ casting or in-situ melting techniques to address the porosity problem. However, in-situ melting technique has not been studied to reduce the porosity of the investment cast aluminium due to the oxidation of the granular aluminium occurs during heating hinders the complete melting of the granules. This research develops a procedure for investment casting of aluminium granules of 99.4% purity by in-situ melting technique. The aluminium granules were filled in ceramic moulds and heated at four different temperatures of 700, 750, 800 and 850°C for 30 and 60 min in a high temperature muffle furnace in ambient. As the heating temperature and duration were increased, the aluminium granules incompletely melt and produced a casting, however the granules agglomerate and replicate the shape of the ceramic mould. The aluminium granules oxidised during heating, encapsulated by a layer of complex oxides composed of stable  $[\alpha\text{-Al}_2\text{O}_3]$ , metastable  $[\gamma\text{-Al}_2\text{O}_3]$  and hydroxides. The thickness of the oxide layer formed on the surface of the air-heated granules increased as the heating temperature and duration were increased. The aluminium granules then were heated at the temperature of 850°C for 30 min in argon environment at the flow rate of argon gas 0.5, 2.5 and 5  $\ell/\text{min}$  to reduce the oxidation of the aluminium granules. The thickness of the oxide layer formed on the argon-heated granule (5  $\ell/\text{min}$ ) was reduced by 60%, but failed to produce a casting. NaCl-KCl flux was applied, which was mixed and sprinkled on the aluminium granules at the Al:Flux ratio of 1:0.2, 1:0.25 and 1:0.33 and heated at the temperature of 850°C for 30 min to break the oxide layer that encapsulate the granules during heating. At the Al:Flux ratio of 1:0.33, 99% of the aluminium granules were successfully melted and produced a casting. The granules began melting at the temperature range 657.2 to 658.4°C and completely melted in 16 min with final melting temperature between 660.1 and 660.6°C. The average porosity level of the casting was 1.22%, which is lower than the investment cast aluminium produced by current pouring technique (2.48%). The low porosity level was attributed to micro-intergranular porosity present in the casting due to volume shrinkage. Investment casting of aluminium granules by in-situ melting technique with application of NaCl-KCl flux at the Al:Flux ratio of 1:0.33 mixed and sprinkled on the granules heated at the temperature of 850°C for 30 min producing low porosity aluminium casting.

## ABSTRAK

Tuangan pelaburan aluminium mengalami kecacatan keliangan dikaitkan dengan kombinasi kompleks beberapa faktor termasuk kualiti leburan, parameter proses tuangan dan teknik menuang. Walaupun rawatan leburan dan kawalan parameter proses mempunyai hasil yang menjanjikan, tetapi gelora terjadi semasa menuang leburan aluminium yang mana meningkatkan pembentukan keliangan akibat kehadiran filem permukaan oksida ( $\text{Al}_2\text{O}_3$ ) yang dinamakan sebagai *bifilm*. Kini, sistem isian bebas gelora telah diaplikasi dalam proses tuangan dengan menggunakan tuangan condong, isian dari bawah dengan tekanan rendah, dan juga tuang secara di situ atau lebur secara di situ untuk mengatasi masalah keliangan. Walaubagaimanapun, teknik lebur secara di situ masih belum dikaji untuk mengurangkan keliangan tuangan pelaburan aluminium kerana pengoksidaan butiran aluminium berlaku semasa pemanasan yang menghalang butiran aluminium melebur dengan sempurna. Kajian ini menghasilkan prosedur tuangan pelaburan butiran aluminium 99.4% tulen dengan teknik lebur di situ. Butiran aluminium dimasukkan ke dalam acuan seramik dan dipanaskan pada empat suhu berbeza iaitu 700, 750, 800 dan 850°C selama 30 dan 60 min di dalam relau *muffle* suhu tinggi secara ambien. Apabila suhu dan tempoh pemanasan dinaikkan, butiran aluminium tidak lebur secara sempurna dan tidak menghasilkan tuangan. Butiran tersebut bergumpal mengikut bentuk acuan seramik. Butiran aluminium teroksida, dirangkum oleh lapisan oksida kompleks [ $\alpha\text{-Al}_2\text{O}_3$ ] stabil, [ $\gamma\text{-Al}_2\text{O}_3$ ] metastabil dan hidroksida. Ketebalan lapisan oksida di permukaan butiran yang dipanaskan dalam udara meningkat apabila suhu dan tempoh pemanasan dinaikkan. Seterusnya, butiran aluminium dipanaskan pada suhu 850°C selama 30 min dalam persekitaran argon dengan kadar alir gas argon 0.5, 2.5 and 5  $\ell/\text{min}$  untuk mengurangkan pengoksidaan butiran aluminium. Ketebalan lapisan oksida di permukaan butiran aluminium yang dipanaskan dalam argon (5  $\ell/\text{min}$ ) berkurang sebanyak 60%, tetapi gagal menghasilkan tuangan. Fluks NaCl-KCl digunakan, dicampur dan ditabur ke atas butiran aluminium pada nisbah Al:Fluks 1:0.2, 1:0.25 and 1:0.33 dan dipanaskan pada suhu 850°C selama 30 min untuk memecahkan lapisan oksida yang merangkum butiran. Pada nisbah Al:Fluks 1:0.33, 99% butiran aluminium berjaya dilebur dan menghasilkan tuangan. Butiran aluminium mula mencair pada julat suhu 657.2 ke 658.4°C dan lengkap melebur dalam masa 16 min dengan julat suhu lebur akhir 660.1 ke 660.6°C. Purata tahap keliangan tuangan ialah 1.22% iaitu lebih rendah berbanding tuangan pelaburan aluminium yang dihasilkan dengan teknik tuangan semasa (2.48%). Tahap keliangan yang rendah dikaitkan dengan keliangan mikro-antarabutiran yang hadir dalam tuangan akibat pengecutan isipadu. Tuangan pelaburan butiran aluminium dengan teknik lebur di situ serta aplikasi fluks NaCl-KCl dengan nisbah Al:Fluks 1:0.33 dicampur dan ditabur atas butiran aluminium serta dipanaskan pada suhu 850°C selama 30 min menghasilkan tuangan aluminium dengan tahap keliangan yang rendah.

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